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BACTERIOLOGICAL WATER QUALITY AND SOURCE IDENTIFICATION AT ST. CATHARINES NEARSHORE JUNE - AUGUST 1983

January, 1986

Ontario
Ministry of the Environment

The Honourable
Jim Bradley
Minister

Rod McLeod
Deputy Minister

BACTERIOLOGICAL WATER QUALITY AND SOURCE IDENTIFICATION AT ST. CATHARINES NEARSHORE JUNE - AUGUST 1983

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EXECUTIVE SUMMARY

Bacteriological water quality at public beaches in the St. Catharines area frequently was found to exceed Provincial Water Quality Objectives for body contact recreation. Fecal coliform levels in excess of 100 organisms per 100 mls were recorded on numerous survey dates. While occasional results indicated levels below the Objective, the geometric mean for fecal coliforms during the study period exceeded the Provincial Objective at all beaches. The bacterial plume originating at the mouth of Twelve Mile Creek greatly affected beaches in its general vicinity while beaches outside the plume were less highly contaminated.

Fecal coliform discharges to the St. Catharines waterfront were found to be substantially higher during and following rain events than during periods of dry weather. Final effluent from the Port Weller and Port Dalhousie STP's generally met Objectives under normal flow conditions; however, Twelve Mile Creek and its tributaries and Walkers Creek were found to continuously exceed Objectives regardless of weather.

Breakwalls situated at the outflow of Twelve Mile Creek and the Welland Ship Canal and extending into the lake may have disrupted current patterns in the nearshore area and resulted in a reduction in assimilative capacity of the receiving water.

1.0 INTRODUCTION

The nearshore area of Lake Ontario at St. Catharines is an area of chronic bacteriological contamination. Beach closures have been frequent due to exceedences of Provincial Water Quality Objectives for body contact recreation.

This problem is thought to arise from municipal and industrial waste inputs entering the waterfront through Twelve Mile Creek, the Welland Ship Canal and other shore discharges.

Surveys were carried out to document bacteriological water quality conditions along the St. Catharines waterfront in Lake Ontario and to identify major potential inputs of bacteria to that nearshore area.

The study was jointly conducted by the Water Resources Branch (Great Lakes Section) and the West-Central Region of the Ontario Ministry of the Environment (MOE), in cooperation with the Niagara Regional Health Unit.

2.0 STUDY AREA AND SURVEY DESIGN

There are four main sources of pollutants to the St. Catharines waterfront (see Figure 1). These are Twelve-Mile Creek (receiving flows from the Old Welland Canal, the Michigan Ditch, and the Port Dalhousie Sewage Treatment Plant); Walkers Creek; the Welland Canal (receiving flows from the Port Weller Sewage Treatment Plant); and four storm sewers which discharge directly to the lake from the St. Catharines shoreline.

The area of investigation for this study, therefore, comprised:

- The Lake Ontario nearshore extending from 1 km west of Twelve Mile Creek to 2 km east of Welland Canal, along an 8 km long and 3 km wide sector covered by 50 sampling locations.

- Six beach monitoring locations previously established by the Niagara Regional Health Unit: Lakeside Beach (East and West), Michigan Beach, Garden City Beach, Municipal Beach and Jones Beach.

- Eight point source inputs including the Port Weller and Port Dalhousie STP effluents, Walkers Creek, four storm sewers discharging directly to Lake Ontario; and the Michigan Ditch, discharging to Port Dalhousie Harbour.

- Four river stations: one in the Old Welland Canal and three in Twelve Mile Creek: one above and one below the confluence with the Old Welland Canal, and one located at the northern extent of Martindale pond.

The study was conducted in three surveys of four, three and three days respectively (June 28 - July 1, August 2 - August 4, August 16 - August 18, 1983). Sampling was carried out through a cooperative effort of the Great Lakes Section (lake sampling), the Welland District Office of the MOE (input and river sampling) and the Niagara Regional Heath Unit (beach sampling).

Samples were collected by boat at all Lake Ontario stations at a depth of 1 m below the water surface, by wading-in to waist depth at the beach locations, and by surface grabs in the river and at point sources.

Note that inclement weather did not permit lake sampling on June 28 and that no beach sampling results from the Health Department are available for August 17 and 18.

Samples were analyzed at the Ministry of the Environment main laboratory in Rexdale; duplicate beach samples were also sent to the Health Department laboratory for purposes of inter-laboratory comparison. Samples were analyzed for fecal coliform bacteria and where possible for *E. coli* and *Pseudomonas aeruginosa* (refer to Figures 1 to 11 for details). Present methods for the analysis of *E. coli* enable reliable quantification. Analytical methods at the time of this survey yielded fecal coliform results with a high degree of confidence; however, *E. coli* results may be suspect and should be regarded with caution.

Flow measurements at all point sources were estimated only during the first portion of the survey (June 28 - July 1). These estimates reflect storm runoff conditions.

3.0 SURVEY RESULTS

3.1 Lake Stations

Exceedences of Provincial Water Quality Objectives for fecal coliform bacteria were found on every survey day for which a sample was obtained (MOE 1984). Figures 2 to 11 give the sampling results for each day.

Bacterial contamination of nearshore waters in these surveys was most evident in the area between the Twelve Mile Creek outlet and the Welland Canal outlet, both of which are protected by breakwall structures which extend some distance into the lake. This area is frequently under the influence of a plume originating at Twelve Mile Creek. An example of this can be seen in Figure 4. Fecal coliform bacteria levels in this zone consistently exceeded the Provincial Objective of 100 organisms/100 mL and often approached 10,000 organisms/100 mL during the sampling period.

Fecal coliform levels up to 1,000 organisms/100 mL also were frequently found to extend over much of the study area (Figures 3, 5, 7, 9, 10, 11), but in general, areas farther offshore exhibited lower bacterial densities than did nearshore areas. The distribution of bacterially contaminated water varied from day to day.

3.2 Twelve Mile Creek (and tributaries)

Bacterial water quality in Twelve Mile Creek upstream of the confluence with Old Welland Canal (Station 24) was generally good and did not exceed the Provincial Objectives for fecal coliform bacteria except during and directly following storm runoff conditions (see for example June 29, 1983, Figure 3).

By contrast, the highest fecal coliform levels recorded in this study were found in the Old Welland Canal (Station 23), which enters Twelve Mile Creek downstream of Station 24.

Fecal coliform densities at this location ranged from 32,000 organisms/100 mL to 650,000 organisms/100 mL. Corresponding E. coli levels were usually much lower (e.g. August 2, Figure 6: Fecal coliforms 300,000 organisms/100 mL vs. E. coli 10,000 organisms 100 mL). Although this survey did not include assays of Klebsiella spp., Hendry (1979) has identified Klebsiella pneumoniae as the dominant bacteria discharged to the Old Welland Canal from several paper companies including the Ontario Paper Company. The analytical procedure for measuring fecal coliform levels does not distinguish between bacteria of enteric origin (such as E. coli) and Klebsiella spp.

Downstream of the Old Welland Canal, Twelve Mile Creek water quality was distinctly inferior to that upstream of the confluence (compare Station 24, upstream, with Station 22, downstream of the confluence, in Figures 2 to 11), although fecal coliform and E. coli levels were lower there than in the Old Welland Canal. An exception to this was August 17 (Figure 10) when E. coli levels were in fact higher in Twelve Mile Creek than in the Old Welland Canal. Note, however, that two survey days - August 17 and 18 - occurred during the Henley Regatta. On those days, flows in Twelve Mile Creek were reduced from an average of approximately 200 m^3/s to 140 m^3/s to accommodate the Regatta, with, presumably, a concomitant reduction in assimilative capacity in the Creek.

Consequently, the relative reduction of fecal coliform levels between Old Welland Canal (Station 23) and the downstream location on Twelve Mile Creek (Station 22) fell from an average of 96% recorded before the Regatta to an average of 81% on August 18 and an apparent increase of 170% on August 17. Note, however, that despite this loss of assimilative capacity, the actual fecal coliform levels at the Twelve Mile Creek mouth (Station 2419) during that time did not change appreciably.

Downstream of Station 22 and close to the Creek outlet, the Michigan Ditch and the Port Dalhousie Sewage Treatment Plant effluent enter Twelve Mile Creek. Results from the Michigan Ditch are only available for August 3, 4, 16, 17 and 18, but these data show high

levels of fecal coliform bacteria (4,100 to 91,000 organisms/100 mL), E. coli (1,000 to 33,000 organisms/100 mL) and Pseudomonas aeruginosa (1,260 to 5,800 organisms/100 mL). Flows in Michigan ditch are extremely low.

The Port Dalhousie sewage treatment plant final effluent showed low bacterial densities during normal flow conditions (7.4 MIGD). Fecal coliform levels at those times (June 30, July 1, August 2, 3, 4, 16, 17 and 18; Figures 4 to 11) were always below 100 organisms/100 mL. Similarly, E. coli and Pseudomonas aeruginosa levels were usually very low, generally less than 10 organisms/100 mL for each.

Following a major rain event (June 27: 22.4 mm; June 28: 12.0 mm), however, bacterial levels in the final effluent increased substantially and remained high for 2 days. On June 28, under average daily flows of 15.22 MIGD and a peak flow of 25 MIGD, fecal coliform levels in the final effluent were 6,000 organisms/100 mL and Pseudomonas aeruginosa concentrations were 220 organisms/100 mL. On the following day, June 29, under resumed normal flow levels of 7.89 MIGD (peak 9.5 MIGD), the fecal coliform levels were still elevated (1,600 organisms/100 mL) and Pseudomonas aeruginosa levels were above the usual level of about 10 organisms/100 mL.

At the outlet of Twelve Mile Creek to Port Dalhousie Harbour, the geometric mean fecal coliform level (for the study period) was 4,303 organisms/100 mL, well above the Provincial Objective of 100 organisms/100 mL. After a heavy rainfall on June 27 (22.4 mm) and June 28 (12.0 mm), fecal coliform levels at the Creek outlet to Lake Ontario exceeded 20,000 organisms/mL. Only once in dry weather sampling did fecal coliform levels at this location fall below 1000 organisms/100 mL.

3.3 Walkers Creek

About 3 km northeast of the Twelve Mile Creek outlet and close to the Garden City Beach, Walkers Creek discharges to Lake Ontario. Flows in this Creek are highly variable and respond quickly to precipitation events. On some survey days however, flows were so low as to be unmeasurable. Fecal coliform levels observed at this location (Station 21) were similarly variable (1,200 to 39,000 organisms/100 mL) and Pseudomonas aeruginosa levels over the same survey period varied from approximately 80 to more than 1,500 organisms/100 mL. E. coli levels at Station 21 were only available for three of the ten survey days and ranged from 100 to 17,000 organisms/100 mL.

3.4 Welland Ship Canal

The Welland Ship Canal enters Lake Ontario about 1 km northeast of the Walkers Creek outlet. Near the mouth of the Canal, in an area protected by breakwalls, is the site of the Port Weller Sewage Treatment Plant effluent discharge. On most of the survey days, fecal coliform levels in the final effluent were below 100 organisms/100 mL under normal flow conditions (6.6 MIGD).

On June 28, however, with daily flows of 14.7 MIGD and a peak flow of 21 MIGD, fecal coliform levels rose to 73,000 organisms/100 mL and Pseudomonas aeruginosa levels exceeded 600 organisms/100 mL. On August 17, under typical flow conditions (6.0 MIGD) but following a by-passing event (0.66 MIGD) of the previous day, fecal coliform levels were 910 organisms/100 mL and Pseudomas aeruginosa approximately 30 organisms/100 mL. Fecal coliform levels at the northern end of the canal breakwall gave a geometric mean of 164 bacteria/100 mL for the study period.

3.5 Waterfront Storm Sewers

Four storm sewers (Stations 32 - 35) discharging directly to Lake Ontario along the St. Catharines waterfront were investigated in this study. All were flowing during the entire study period, including dry weather days.

Results of the storm sewer investigations (Table 1) show relatively low flows at all four locations, and fecal coliform levels lower than at many lake and river stations studied during the same time period. However, E. coli comprised up to 68% of the fecal bacterial flora observed in the sewers - a somewhat higher proportion than was found in the lake and river stations.

3.6 Beach Sampling Locations

Five beaches were investigated during this study: Lakeside Beach, situated west of the Twelve Mile Creek pier; Michigan Beach, located on the eastern side of Twelve Mile Creek breakwall; Garden City and Municipal Beaches, located west of the Welland Canal breakwall; and Jones Beach, situated just east of the Welland Canal breakwall (see Figure 1). Of these, Lakeside Beach is the largest and most extensively used by the public. For this reason it was sampled at two locations (near its eastern boundary - Station 2452, and near its western boundary - Station 2451). A brief data summary is provided in Table 2.

The results of this investigation show that all the St. Catharines beaches exhibited geometric mean fecal coliform levels exceeding Provincial Objectives for body contact recreation during the study period. The highest levels were found at the Garden City Beach, close to the outlet of Walkers Creek. MOE survey results for the other four beaches are not in complete agreement with Niagara Regional Health Unit data but indicate somewhat less degraded water quality at Municipal Beach, Michigan Beach, and Lakeside Park East. Better water quality was observed at Jones Beach and Lakeside Park West.

Health Unit sampling results showed similar conditions at all stations except Garden City Beach, which had the highest bacterial densities of the beach stations. The discrepancy between MOE and Health Unit data may be due in part to reporting protocol and possible analytical differences between the MOE and Health Department laboratories. While the MOE laboratory attempts to quantify all bacterial densities, the Health Department laboratory does not report true values greater than 240 fecal coliform organisms/100 mL. This practice results not only in underestimates of bacterial densities but also loss in determining significant spatial differences.

4.0 DISCUSSION

The Lake Ontario nearshore area at St. Catharines is clearly influenced by bacterial inputs from the St. Catharines waterfront. Of these, it is likely that Twelve Mile Creek is the most significant contributor. Bacterial levels in the Creek were high, especially after storm events, and this, coupled with high discharge volumes (an average of 200 m^3/s), results in substantial loadings of bacteria to the lake (an estimated average of 8.39×10^9 fecal coliform organisms/second during the survey period).

The most significant source of bacterial contamination in the Creek is the Old Welland Canal, which receives effluents from the Ontario Paper Company and other paper mills. Although its flows are only a fraction of those in the Creek (3.6 m^3/s vs. 200 m^3/s) its extremely high concentrations make a significant deleterious contribution to the water quality in Twelve Mile Creek. Other sources to the Creek, such as the Port Dalhousie STP and the Michigan Ditch under dry weather conditions are minor by comparison. Effluent bacterial contamination from the Port Dalhousie STP during and after storm events likely contributes significantly to fecal coliform levels in Twelve Mile Creek. Occasionally elevated E. coli levels downstream of the Old Welland Canal suggests a source in that area which may warrant further investigation.

For two days of the survey (August 17 and 18) flows in Twelve Mile Creek were reduced from an average of about 200 m^3/s to about 140 m^3/s to accommodate the Henley Regatta. This drop in flow effectively reduced the assimilative capacity of Twelve Mile Creek, especially in its ability to dilute inputs from the Old Welland Canal, although water quality at the mouth of the Creek was apparently unaffected.

Walkers Creek, which enters the waterfront northeast of Twelve Mile Creek, was found to contribute small but variable loads of bacteria to the lake. Flows were low enough to be unmeasurable for some survey days, so corresponding loadings observed during the survey were not high enough to constitute a major source. However, typically flashy (short) response of such a small creek to rainfall events may

have been missed during the survey which was designed primarily as a screening investigation and not an in-depth evaluation of all sources. Pollutograph based investigations may well find contributions from this creek to be significant for short periods of time in response to rainfall. Furthermore in view of the proximity of this source to Garden City Beach and the restricted nearshore circulation in the area between the Twelve Mile Creek and Welland Ship Canal breakwalls, this creek has a potential of significantly degrading water quality in its immediate vicinity.

Waterfront storm sewers also contribute variable bacterial loads to the nearshore area. Dry and wet weather inputs were observed at these locations. Further action should be taken to determine quantitative loadings from these sources through storm pollutograph measurements. Presence of dry weather flows detected in those sewers should prompt an investigation of illegal or cross connections in their drainage areas.

Flows in the Welland Ship Canal, northeast of Walker's Creek, are moderate, but under storm conditions high bacterial contributions attributable to bypassing at the Port Weller sewage treatment plant can constitute a major source of contamination to the waterfront.

All of the St. Catharines waterfront beaches had water quality exceeding the Provincial Water Quality Objectives for body contact recreation (based on fecal coliforms) during the survey period. The Garden City Beach appeared to be most degraded bacteriologically, probably because of the combined contributions from Twelve Mile Creek and nearby Walkers Creek. MOE results showed Lakeside Park East, Michigan Beach and Municipal Beach to be intermediate in bacteriological water quality. All three of those beaches are located within the Twelve Mile Creek plume which frequently envelopes the area between the breakwalls of the Port Dalhousie and Port Weller Harbours and extends westwards through the open-piered breakwall at Port Dalhousie towards Lakeside beach. The least affected beaches, Lakeside Park West and Jones Beach, are located near the western and eastern boundaries of the study area and thus farthest away from the immediate impact of the Twelve Mile Creek plume.

These results suggest that the Port Dalhousie and Port Weller breakwalls may restrict waterfront circulation and therefore lead to localized bacterial concentrations from the Twelve Mile Creek plume and other sources in the nearshore area which would normally undergo dilution.

5.0 CONCLUSIONS

1. All of the St. Catharines waterfront beaches surveyed had water quality which, based on Provincial Objectives, was unsuitable for body contact recreation. Beaches in the central waterfront area, where several sources come together, were more severely contaminated than those on the fringes of the study area.

2. Twelve Mile Creek was the most significant contributor of bacterial loadings to the St. Catharines waterfront during the study period.

3. The Old Welland Canal was the prime source of bacterial contaminants to Twelve Mile Creek.

4. Bacterial loadings from sewage treatment plants increased substantially during and following rainfall events and contribute to impairment of water quality. Contributions during dry weather normally fall within estabished guidelines.

5. Other sources to the waterfront such as Walkers Creek, the Welland Ship Canal and waterfront storm sewers, contribute variable bacterial loads to the nearshore area. Under storm conditions, certain of these can yield significant loads of bacteria to the waterfront.

6. The breakwalls at Port Dalhousie and Port Weller harbours may restrict circulation and "flushing" of bacterial contamination from the central waterfront area.

REFERENCES

Hendry, G. S. 1979. The Bacteriological Water Quality of the Old Welland Canal and Twelve Mile Creek, 1978, Effects of Wastes from Pulp and Paper Operations. Unpublished report, Ontario Ministry of the Environment.

Ontario Ministry of the Environment 1984. Water Management Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment.

TABLE 1

Bacterial Levels in Effluents of St. Catharines Waterfront Storm Sewers, during the survey*.

			Density (organisms/100 mls)			
Stn.	Sewer Location	Sewer diameter (inches)	Fecal** Coliforms	% *E. coli****	*Pseudomonas* *aeruginosa**	Range of Flows June 28 - July 1 (gallons/min.)
32	Lake Street	27	817	68	170	trace
33	Beachview Dr.W.	48	546	63	281	2 - 10
34	Beachview Dr.E.	24	445	50	397	3 - 10
35	Mouth of Spring Garden Cr.	42	3747	46	283	1 - 6

* survey days : June 29 - 30, Aug. 2 - 4, 16 - 18, 1983
** 10 day geometric mean
*** % of *E. coli* within Fecal coliform geometric mean

<u>TABLE 2</u>

Fecal coliform levels at St. Catharines beaches during the survey*.

	MOE results (G.M.) organisms/100 mL.	Health Unit results (G.M.) organisms/100 mL.
Lakeside Park W.	119	139
Lakeside Park E.	291	113
Michigan Beach	349	148
Garden City Beach	594	240
Municipal Beach	350	135
Jones Beach	152	134

Note: All laboratory results were taken at face values (including less than and greater than numbers) in computing the above geometric means (G.M.).

* Survey days: June 28, 29, 30, Aug. 2, 3, 4, 18 - all stations sampled except Municipal beach which was not sampled on Aug. 3 or 18.

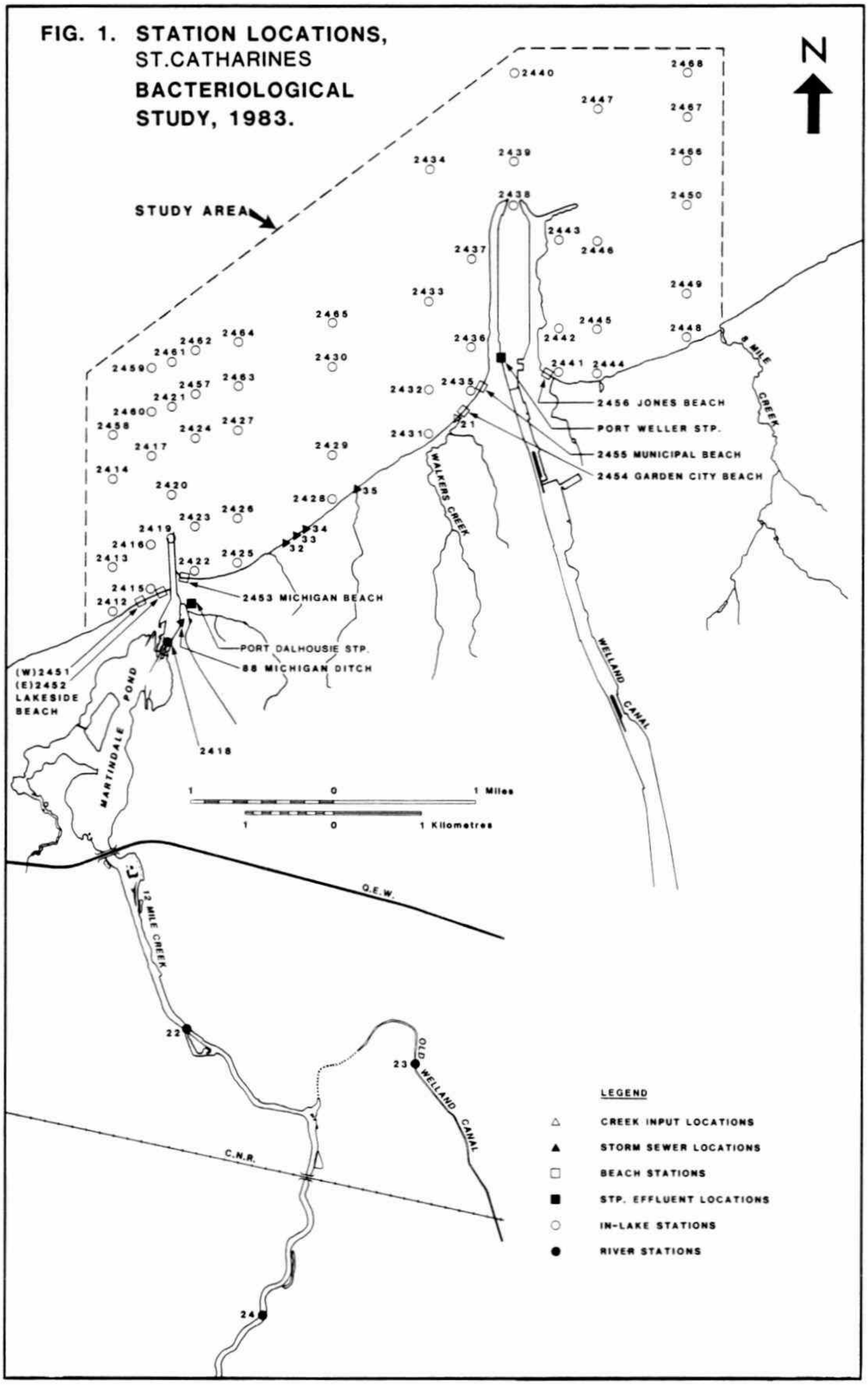
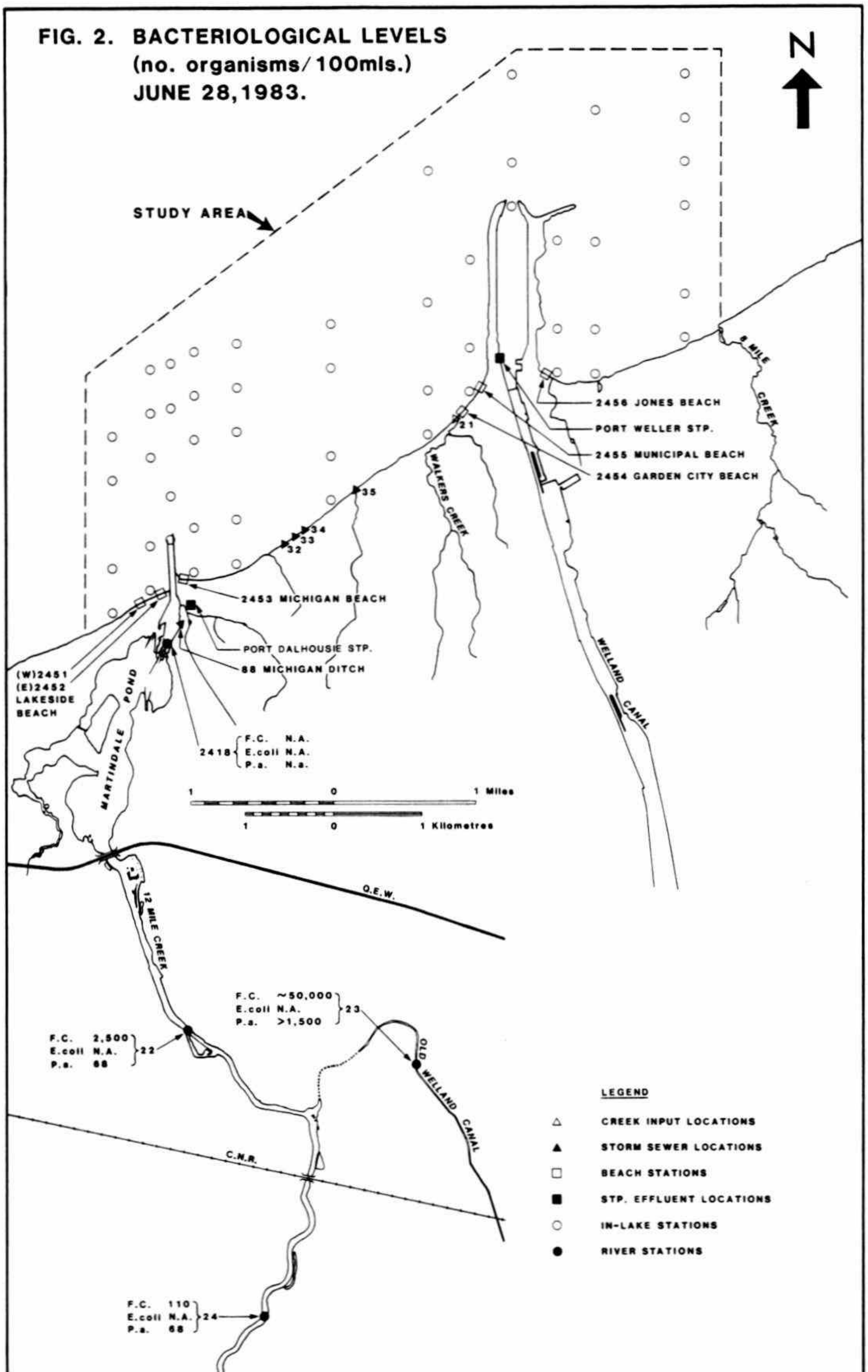


FIG. 1. STATION LOCATIONS, ST.CATHARINES BACTERIOLOGICAL STUDY, 1983.

FIG. 2. BACTERIOLOGICAL LEVELS
(no. organisms/100mls.)
JUNE 28,1983.



BEACHES

	LAKESIDE W(2451)	LAKESIDE E(2452)	MICHIGAN (2453)	GARDEN CITY (2454)	MUNICIPAL (2455)	JONES (2456)
F.C.	~6,000	~6,000	~900	320	200	5,900
E.coli	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
P.a.	56	72	24	4	8	>600

INPUTS

	PORT DELHOUSIE STP.	STORM (32)	WALKERS CR. (21)	PORT WELLER STP.
F.C.	6,000	>600	15,000	73,000
E.coli	N.A.	N.A.	N.A.	N.A.
P.a.	220	>300	>600	>600

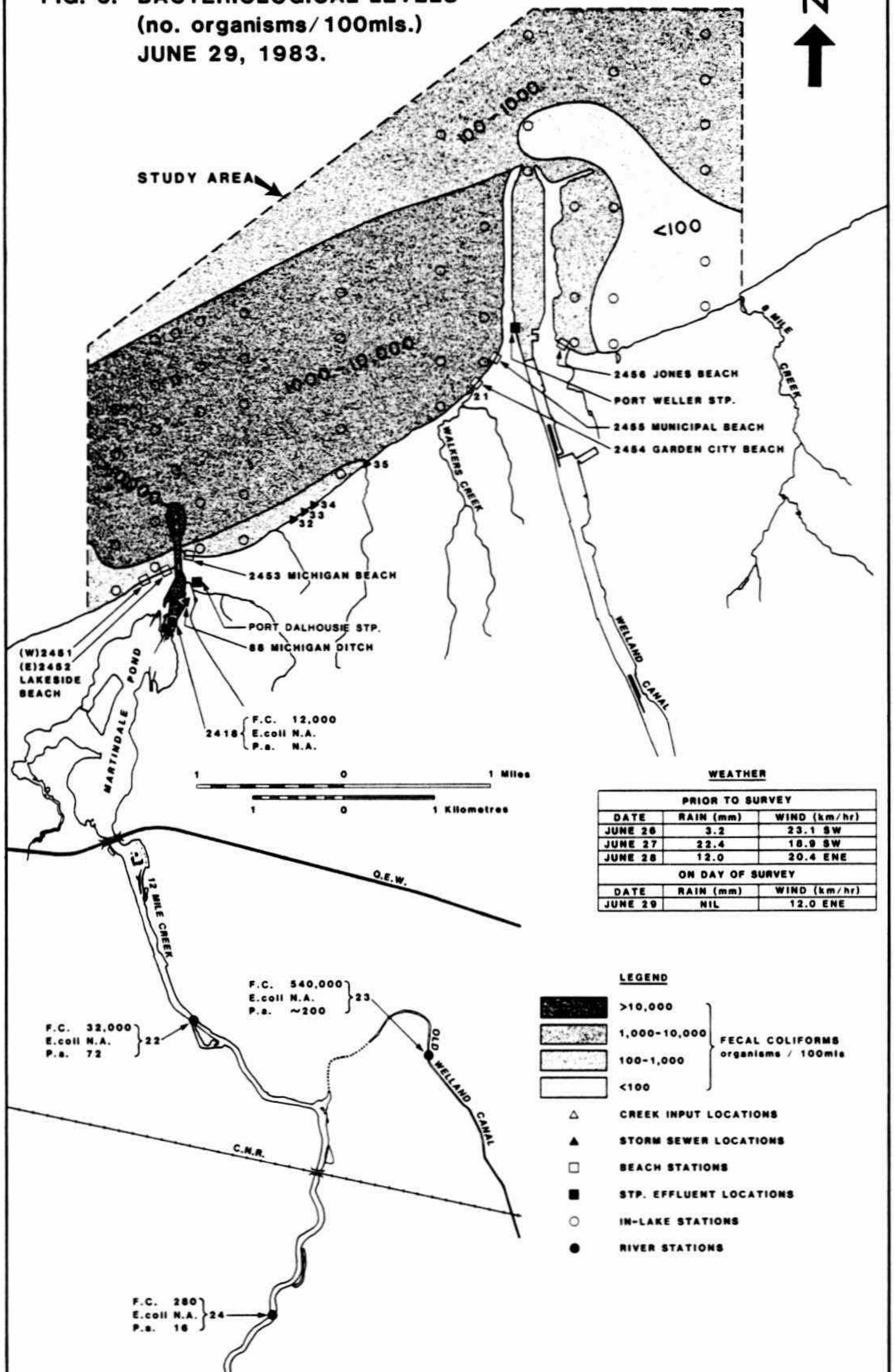
	MICHIGAN DITCH (88)	STORM (33)
F.C.	N.A.	>3,000
E.coli	N.A.	N.A.
P.a.	N.A.	>300

	STORM (34)	STORM (35)
F.C.	370	7,300
E.coli	N.A.	N.A.
P.a.	>600	>600

NOTE:

F.C. FECAL COLIFORMS
E.coli ESCHERICHIA COLI
P.a. PSEUDOMONAS AERUGINOSA
N.A. NOT AVAILABLE

FIG. 3. BACTERIOLOGICAL LEVELS (no. organisms/ 100mls.) JUNE 29, 1983.



WEATHER

PRIOR TO SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
JUNE 26	3.2	23.1 SW
JUNE 27	22.4	18.9 SW
JUNE 28	12.0	20.4 ENE
ON DAY OF SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
JUNE 29	NIL	12.0 ENE

LEGEND

- >10,000
- 1,000-10,000
- 100-1,000
- <100

FECAL COLIFORMS organisms / 100mls

- △ CREEK INPUT LOCATIONS
- ▲ STORM SEWER LOCATIONS
- □ BEACH STATIONS
- ■ STP. EFFLUENT LOCATIONS
- ○ IN-LAKE STATIONS
- ● RIVER STATIONS

BEACHES

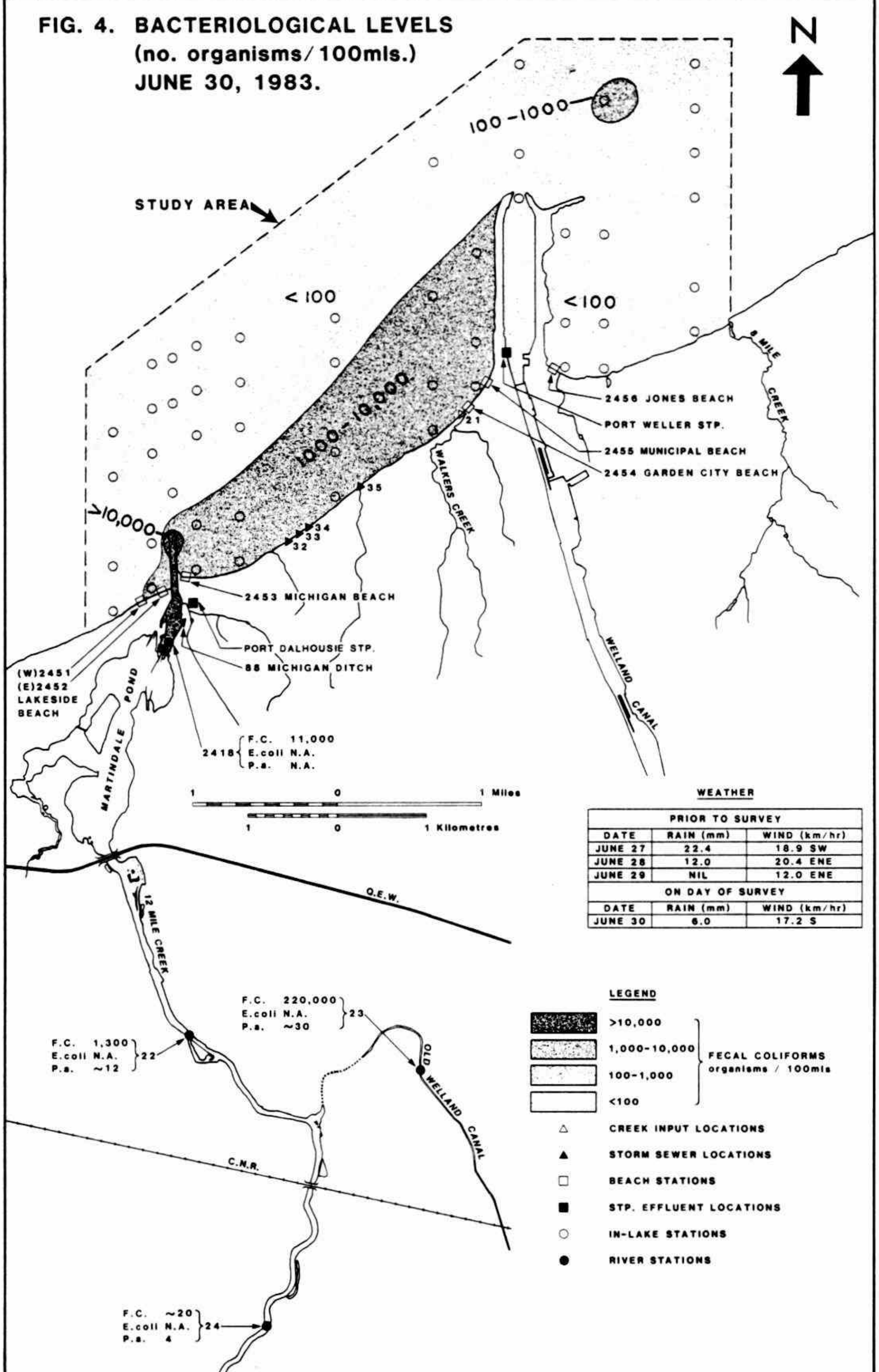
	LAKESIDE W(2451)	LAKESIDE E(2452)	MICHIGAN (2453)	GARDEN CITY (2454)	MUNICIPAL (2455)	JONES (2456)
F.C.	~2,000	2,900	3,800	~1,900	~900	~800
E.coli	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
P.a.	24	36	~24	~24	12	190

INPUTS

	PORT DELHOUSIE STP.	MICHIGAN DITCH (88)	STORM (32)	STORM (33)	STORM (34)	STORM (35)	WALKERS CR. (21)	PORT WELLER STP.
F.C.	1,600	N.A.	500	830	~40	38,000	14,000	<100
E.coli	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
P.a.	50	N.A.	~50	110	12	~30	760	<10

NOTE:

F.C. FECAL COLIFORMS
E.coli ESCHERICHIA COLI
P.a. PSEUDOMONAS AERUGINOSA
N.A. NOT AVAILABLE



WEATHER

PRIOR TO SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
JUNE 27	22.4	18.9 SW
JUNE 28	12.0	20.4 ENE
JUNE 29	NIL	12.0 ENE
ON DAY OF SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
JUNE 30	6.0	17.2 S

LEGEND

- >10,000
- 1,000-10,000
- 100-1,000
- <100

FECAL COLIFORMS organisms / 100mls

- △ CREEK INPUT LOCATIONS
- ▲ STORM SEWER LOCATIONS
- □ BEACH STATIONS
- ■ STP. EFFLUENT LOCATIONS
- ○ IN-LAKE STATIONS
- ● RIVER STATIONS

BEACHES

	LAKESIDE W(2451)	LAKESIDE E(2452)	MICHIGAN (2453)	GARDEN CITY (2454)	MUNICIPAL (2455)	JONES (2456)
F.C.	~100	~100	1,200	900	12,000	~100
E.coli	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
P.a.	<10	<10	<10	~8	<4	40

INPUTS

	PORT DELHOUSIE STP.	STORM (32)	WALKERS CR. (21)	PORT WELLER STP.
F.C.	<100	500	1,200	10
E.coli	N.A.	N.A.	N.A.	N.A.
P.a.	<10	24	<1,000	<10

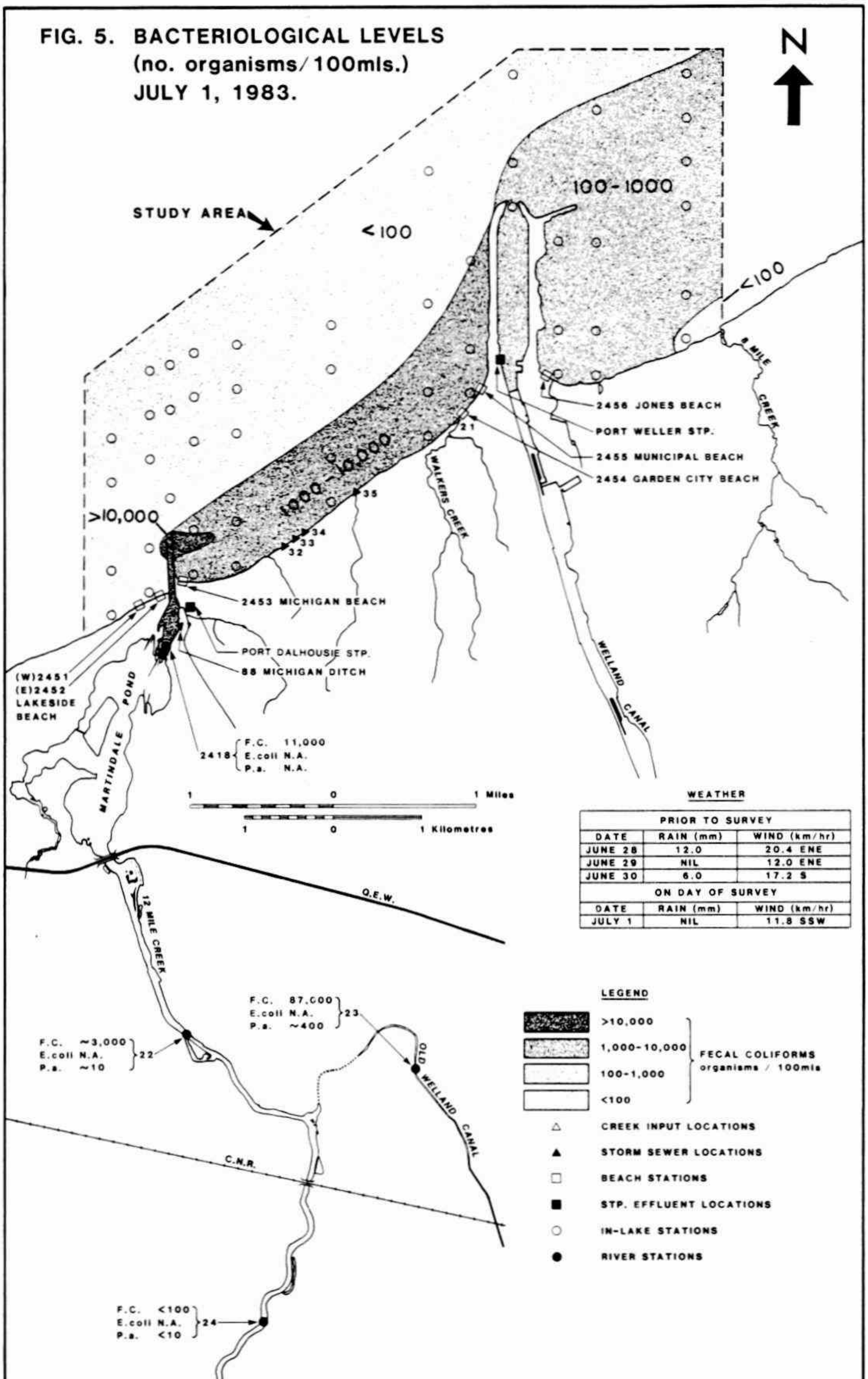
	MICHIGAN DITCH (88)	STORM (33)
F.C.	N.A.	~70
E.coli	N.A.	N.A.
P.a.	N.A.	~40

	STORM (34)	STORM (35)
F.C.	~60	1,000
E.coli	N.A.	N.A.
P.a.	130	~100

NOTE:

F.C. FECAL COLIFORMS
E.coli ESCHERICHIA COLI
P.a. PSEUDOMONAS AERUGINOSA
N.A. NOT AVAILABLE

FIG. 5. BACTERIOLOGICAL LEVELS (no. organisms/100mls.) JULY 1, 1983.



WEATHER

PRIOR TO SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
JUNE 28	12.0	20.4 ENE
JUNE 29	NIL	12.0 ENE
JUNE 30	6.0	17.2 S
ON DAY OF SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
JULY 1	NIL	11.8 SSW

BEACHES

	LAKESIDE W(2451)	LAKESIDE E(2452)	MICHIGAN (2453)	GARDEN CITY (2454)	MUNICIPAL (2455)	JONES (2456)
F.C.	~100	220	~400	1,900	3,300	170
E.coli	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
P.a.	8	<4	4	60	400	4

INPUTS

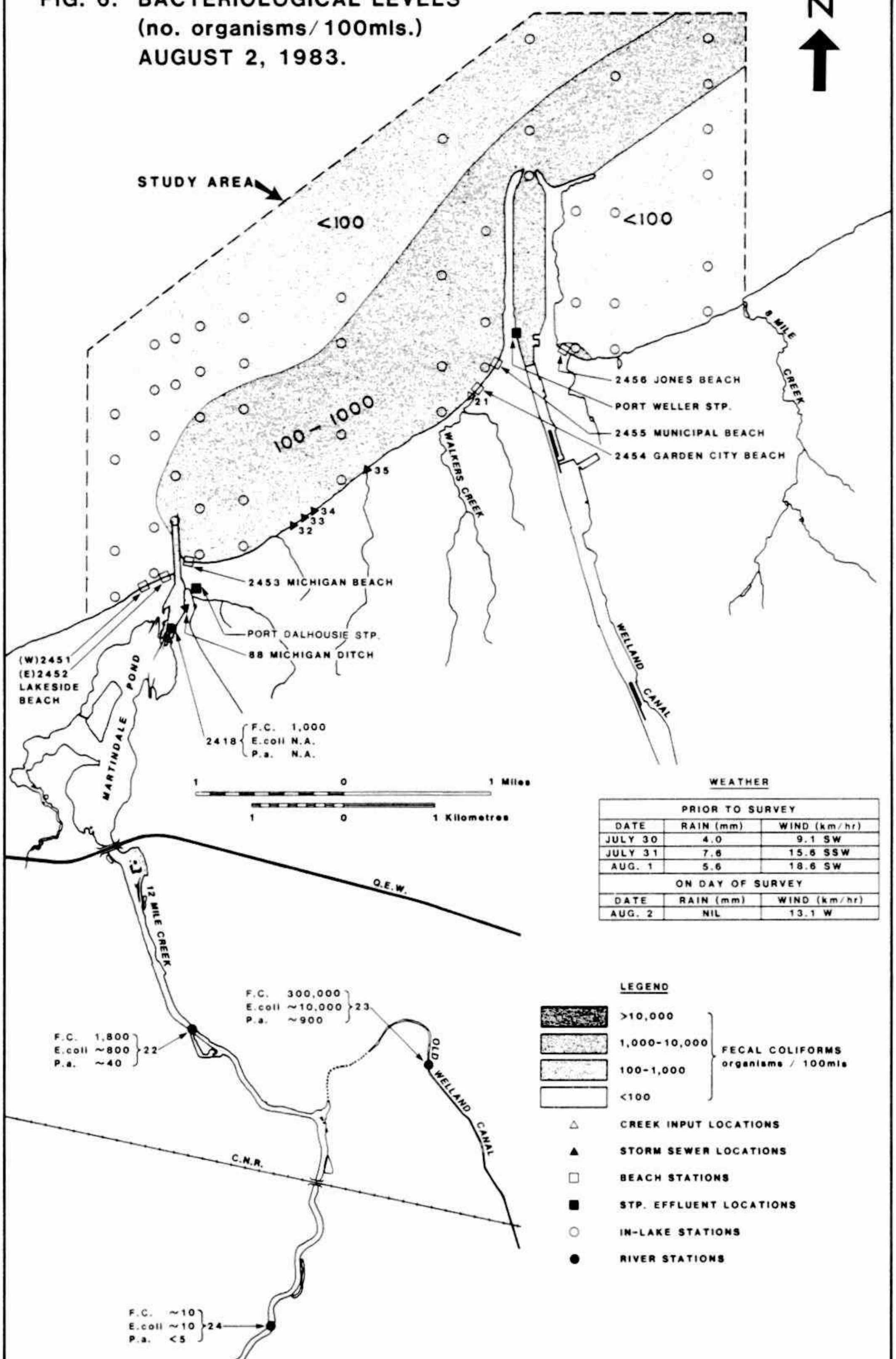
	PORT DELHOUSIE STP.	STORM (32)	WALKERS CR. (21)	PORT WELLER STP.
F.C.	<10	1,100	9,500	~10
E.coli	N.A.	N.A.	N.A.	N.A.
P.a.	<4	88	400	<4

	MICHIGAN DITCH (88)	STORM (33)	STORM (34)	STORM (35)
F.C.	N.A.	385	25	2,400
E.coli	N.A.	N.A.	N.A.	N.A.
P.a.	N.A.	42	88	~20

NOTE:

F.C. FECAL COLIFORMS
E.coli ESCHERICHIA COLI
P.a. PSEUDOMONAS AERUGINOSA
N.A. NOT AVAILABLE

FIG. 6. BACTERIOLOGICAL LEVELS (no. organisms/ 100mls.) AUGUST 2, 1983.



WEATHER

PRIOR TO SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
JULY 30	4.0	9.1 SW
JULY 31	7.6	15.6 SSW
AUG. 1	5.6	18.6 SW
ON DAY OF SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
AUG. 2	NIL	13.1 W

BEACHES

	LAKESIDE W(2451)	LAKESIDE E(2452)	MICHIGAN (2453)	GARDEN CITY (2454)	MUNICIPAL (2455)	JONES (2456)
F.C.	~700	500	190	1,000	1,500	1,600
E.coli	~400	260	~50	~700	500	1,300
P.a.	<4	12	8	164	60	72

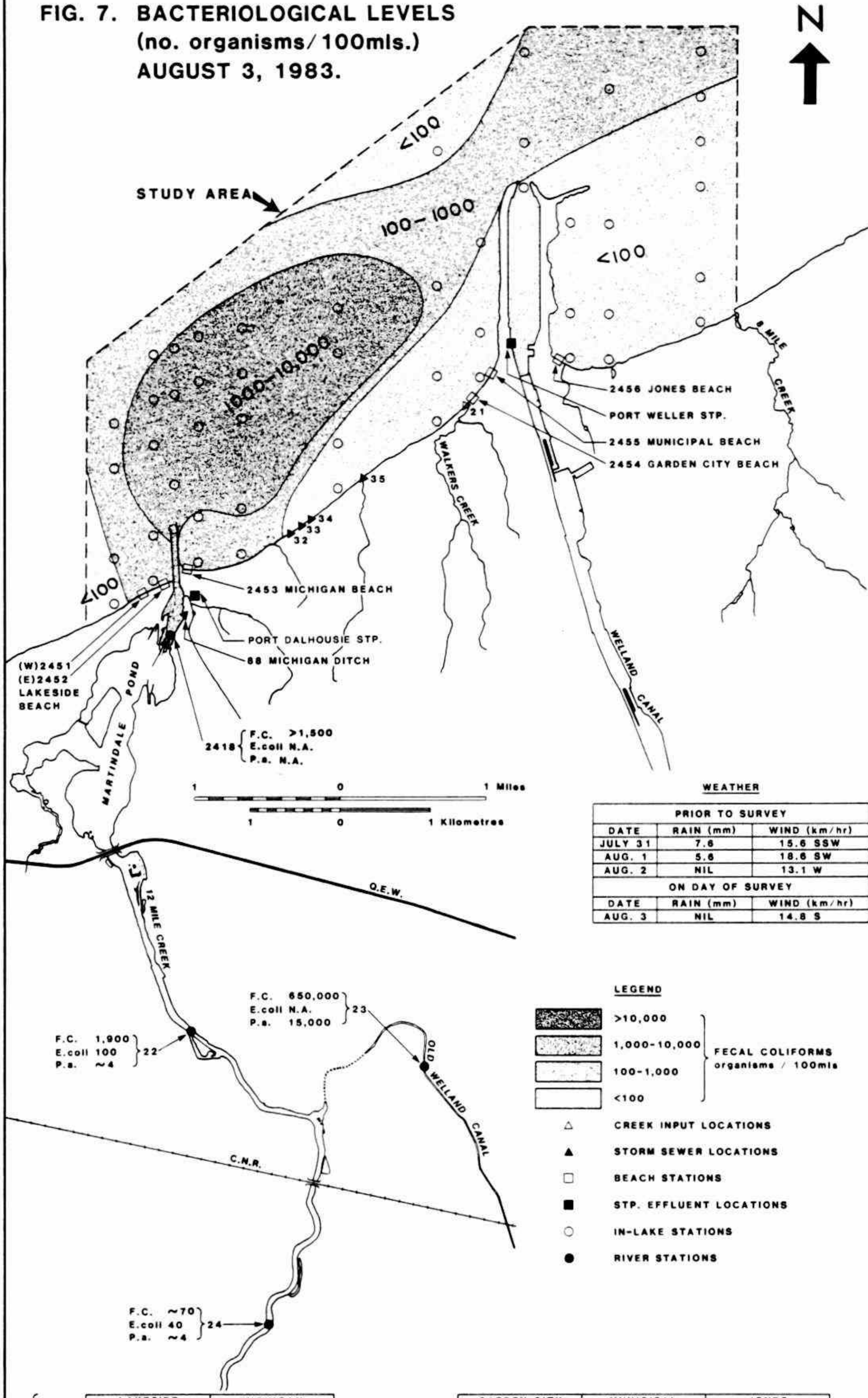
INPUTS

	PORT DELHOUSIE STP.	MICHIGAN DITCH (88)	STORM (32)	STORM (33)	STORM (34)	STORM (35)	WALKERS CR. (21)	PORT WELLER STP.
F.C.	<10	N.A.	800	2,300	1,600	6,700	3,500	<10
E.coli	<10	N.A.	700	1,500	300	2,500	1,100	<10
P.a.	<4	N.A	>600	245	>750	>750	550	4

NOTE:

F.C. FECAL COLIFORMS
E.coli ESCHERICHIA COLI
P.a. PSEUDOMONAS AERUGINOSA
N.A. NOT AVAILABLE

FIG. 7. BACTERIOLOGICAL LEVELS (no. organisms/ 100mls.) AUGUST 3, 1983.



WEATHER

PRIOR TO SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
JULY 31	7.6	15.6 SSW
AUG. 1	5.6	18.6 SW
AUG. 2	NIL	13.1 W
ON DAY OF SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
AUG. 3	NIL	14.8 S

BEACHES

	LAKESIDE W(2451)	LAKESIDE E(2452)	MICHIGAN (2453)	GARDEN CITY (2454)	MUNICIPAL (2455)	JONES (2456)
F.C.	180	920	~700	~300	<100	110
E.coli	150	810	<100	~300	<100	70
P.a.	16	84	~68	64	12	8

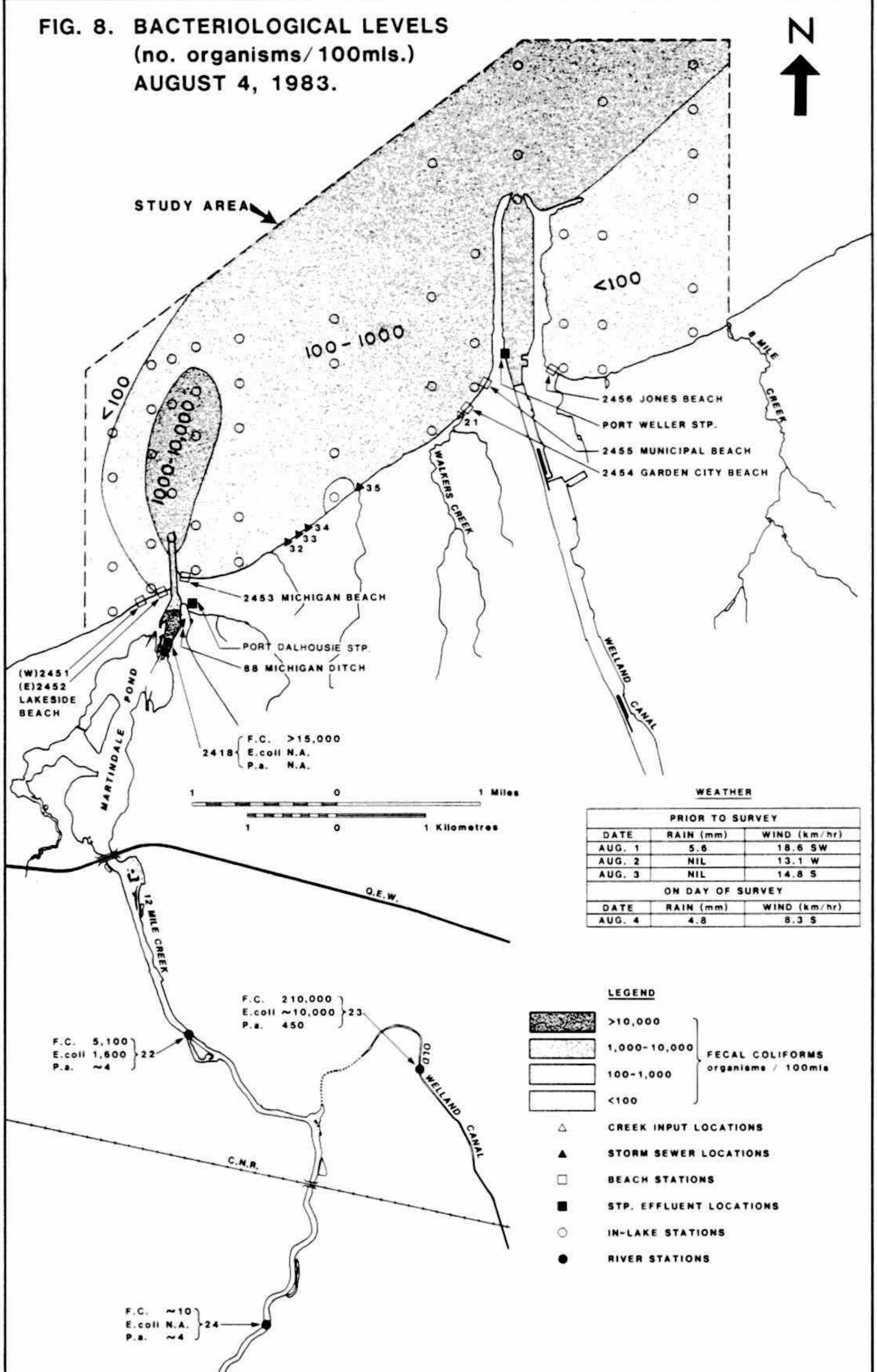
INPUTS

	PORT DELHOUSIE STP.	MICHIGAN DITCH (88)	STORM (32)	STORM (33)	STORM (34)	STORM (35)	WALKERS CR. (21)	PORT WELLER STP.
F.C.	10	91,000	1,800	530	310	6,300	1,400	90
E.coli	~10	33,000	1,400	240	250	4,200	N.A.	80
P.a.	<4	3,700	92	120	104	>600	260	~16

NOTE:

F.C. FECAL COLIFORMS
E.coli ESCHERICHIA COLI
P.a. PSEUDOMONAS AERUGINOSA
N.A. NOT AVAILABLE

FIG. 8. BACTERIOLOGICAL LEVELS (no. organisms/100mls.) AUGUST 4, 1983.



WEATHER

PRIOR TO SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
AUG. 1	5.6	18.6 SW
AUG. 2	NIL	13.1 W
AUG. 3	NIL	14.8 S
ON DAY OF SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
AUG. 4	4.8	8.3 S

BEACHES

	LAKESIDE W(2451)	LAKESIDE E(2452)	MICHIGAN (2453)	GARDEN CITY (2454)	MUNICIPAL (2455)	JONES (2456)
F.C.	~20	~90	~590	260	70	~10
E.coli	20	90	30	180	~10	<10
P.a.	<4	~20	~112	92	<4	4

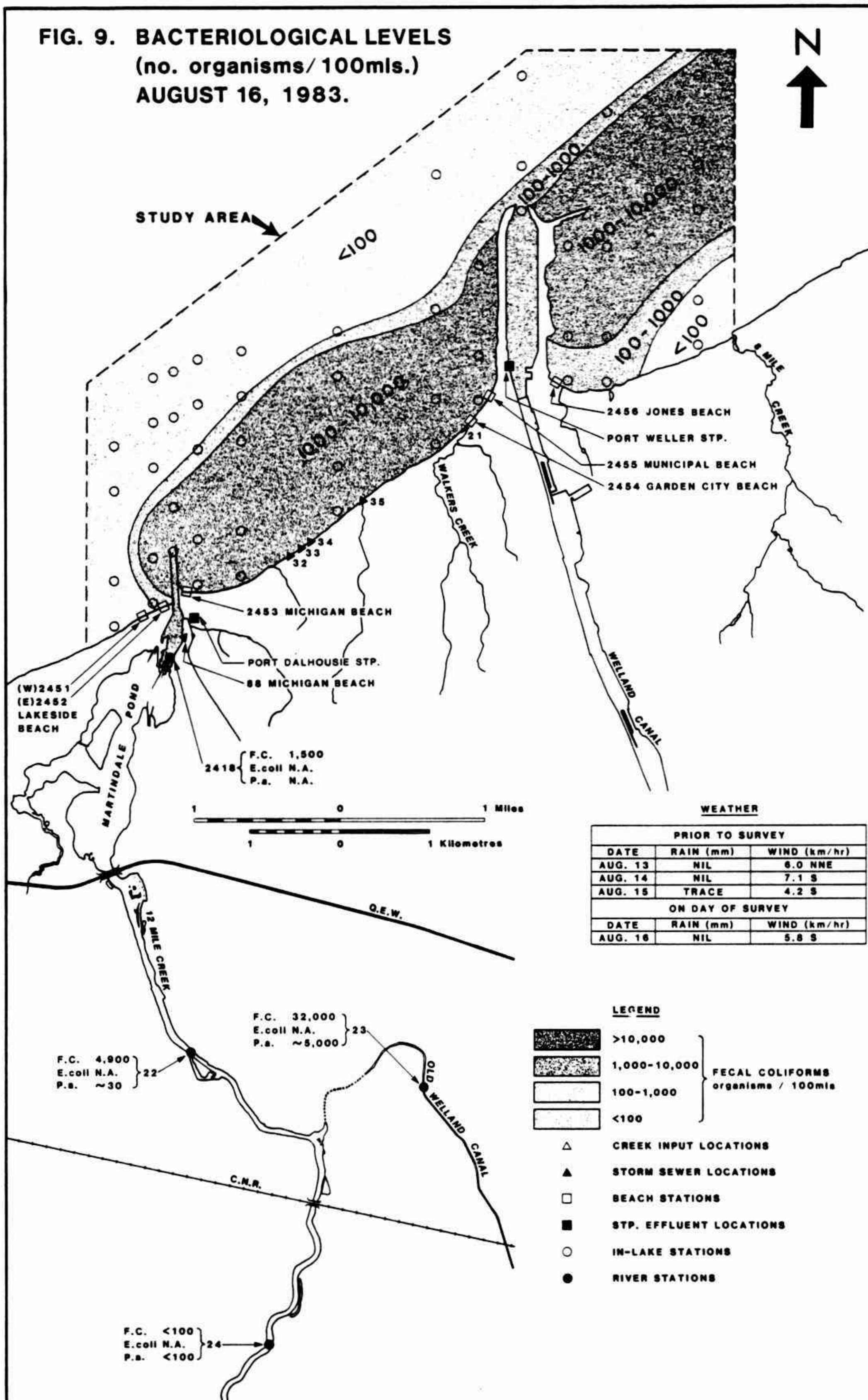
INPUTS

	PORT DELHOUSIE STP.	MICHIGAN DITCH (88)	STORM (32)	STORM (33)	STORM (34)	STORM (35)	WALKERS CR. (21)	PORT WELLER STP.
F.C.	5	28,000	8,000	790	400	9,700	39,000	30
E.coli	<5	20,000	5,800	510	350	5,100	17,000	~30
P.a.	~24	5,600	>600	>600	452	>600	>1,500	~4

NOTE:

F.C. FECAL COLIFORMS
E.coli ESCHERICHIA COLI
P.a. PSEUDOMONAS AERUGINOSA
N.A. NOT AVAILABLE

FIG. 9. BACTERIOLOGICAL LEVELS (no. organisms/ 100mls.) AUGUST 16, 1983.



WEATHER

PRIOR TO SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
AUG. 13	NIL	6.0 NNE
AUG. 14	NIL	7.1 S
AUG. 15	TRACE	4.2 S
ON DAY OF SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
AUG. 16	NIL	5.8 S

LEGEND

- >10,000 — FECAL COLIFORMS organisms / 100mls
- 1,000-10,000 — FECAL COLIFORMS organisms / 100mls
- 100-1,000 — FECAL COLIFORMS organisms / 100mls
- <100 — FECAL COLIFORMS organisms / 100mls
- △ CREEK INPUT LOCATIONS
- ▲ STORM SEWER LOCATIONS
- □ BEACH STATIONS
- ■ STP. EFFLUENT LOCATIONS
- ○ IN-LAKE STATIONS
- ● RIVER STATIONS

BEACHES

	LAKESIDE W(2451)	LAKESIDE E(2452)	MICHIGAN (2453)	GARDEN CITY (2454)	MUNICIPAL (2455)	JONES (2456)
F.C.	230	110	13,000	>15,000	>15,000	150
E.coli	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
P.a.	<4	52	~20	~25	~5	~40

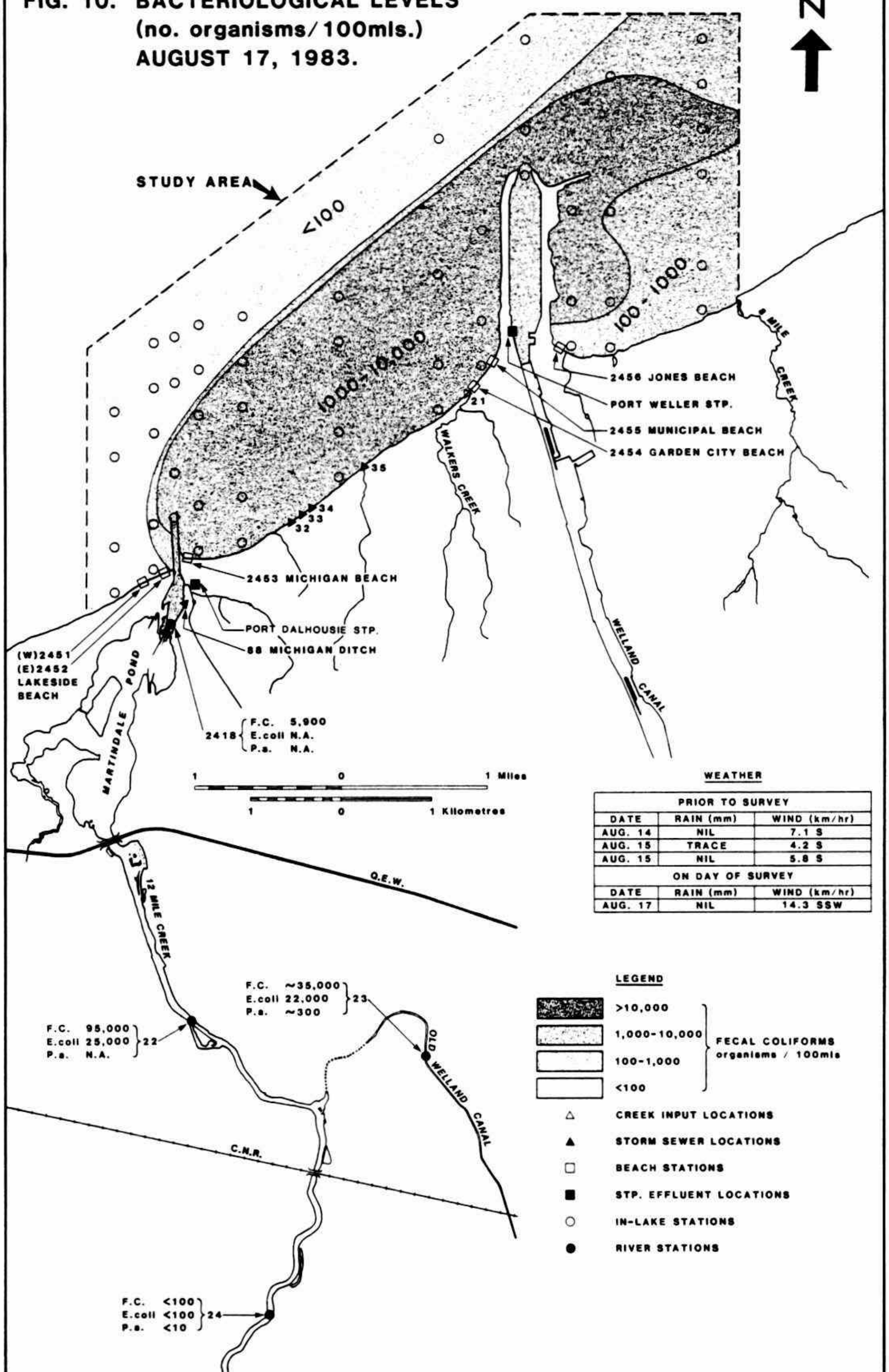
INPUTS

	PORT DELHOUSIE STP.	MICHIGAN DITCH (88)	STORM (32)	STORM (33)	STORM (34)	STORM (35)	WALKERS CR. (21)	PORT WELLER STP.
F.C.	25	4,100	550	580	5,500	1,000	6,300	100
E.coli	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
P.a.	<10	5,800	>1,500	>1,500	>15,000	900	~80	<100

NOTE:

F.C. FECAL COLIFORMS
E.coli ESCHERICHIA COLI
P.a. PSEUDOMONAS AERUGINOSA
N.A. NOT AVAILABLE

FIG. 10. BACTERIOLOGICAL LEVELS (no. organisms/100mls.) AUGUST 17, 1983.



WEATHER

PRIOR TO SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
AUG. 14	NIL	7.1 S
AUG. 15	TRACE	4.2 S
AUG. 15	NIL	5.8 S
ON DAY OF SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
AUG. 17	NIL	14.3 SSW

BEACHES

	LAKESIDE W(2451)	LAKESIDE E(2452)	MICHIGAN (2453)	GARDEN CITY (2454)	MUNICIPAL (2455)	JONES (2456)
F.C.	320	40	4,500	2,100	1,500	150
E.coli	240	~10	3,200	1,500	1,000	~50
P.a.	<4	<4	8	~10	<5	<10

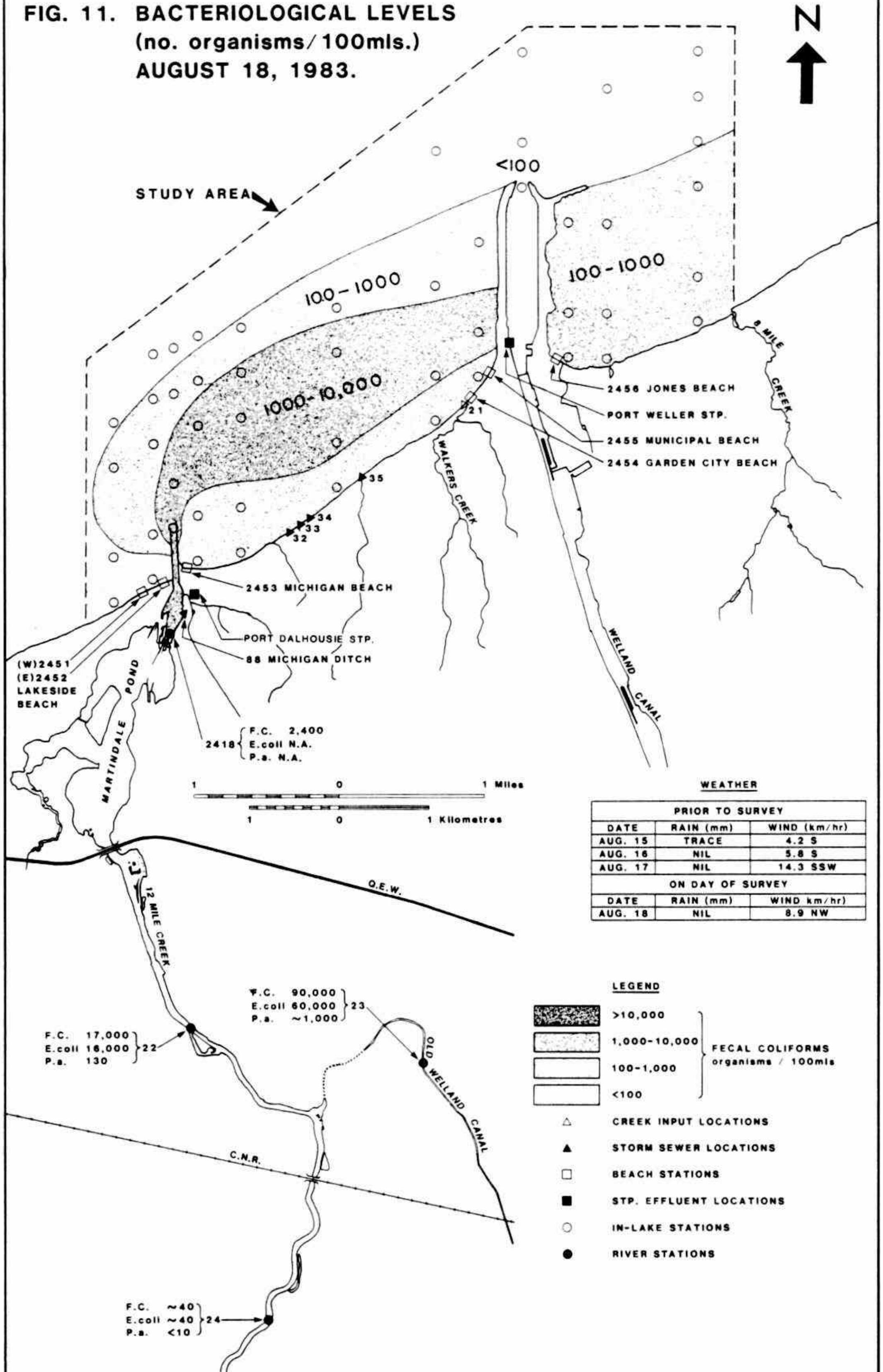
INPUTS

	PORT DALHOUSIE STP.	MICHIGAN DITCH (88)	STORM (32)	STORM (33)	STORM (34)	STORM (35)	WALKERS CR. (21)	PORT WELLER STP.
F.C.	35	6,000	600	210	6,300	2,600	1,300	910
E.coli	<5	1,000	~200	140	2,900	500	<100	470
P.a.	<10	1,260	270	1,390	>1,500	1,360	240	~30

NOTE:

F.C. FECAL COLIFORMS
E.coli ESCHERICHIA COLI
P.a. PSEUDOMONAS AERUGINOSA
N.A. NOT AVAILABLE

FIG. 11. BACTERIOLOGICAL LEVELS (no. organisms/100mls.) AUGUST 18, 1983.



WEATHER

PRIOR TO SURVEY		
DATE	RAIN (mm)	WIND (km/hr)
AUG. 15	TRACE	4.2 S
AUG. 16	NIL	5.8 S
AUG. 17	NIL	14.3 SSW
ON DAY OF SURVEY		
DATE	RAIN (mm)	WIND km/hr)
AUG. 18	NIL	8.9 NW

BEACHES

	LAKESIDE W(2451)	LAKESIDE E(2452)	MICHIGAN (2453)	GARDEN CITY (2454)	MUNICIPAL (2455)	JONES (2456)
F.C.	~80	160	190	1,600	500	300
E.coli	40	140	120	~100	500	200
P.a.	<4	4	<20	<4	~5	~10

INPUTS

	PORT DELHOUSIE STP.	MICHIGAN DITCH (88)	STORM (32)	STORM (33)	STORM (34)	STORM (35)	WALKERS CR. (21)	PORT WELLER STP.
F.C.	15	16,000	210	300	>1,500	770	>15,000	20
E.coli	<5	16,000	180	240	N.A.	650	N.A.	~10
P.a.	<10	5,700	~50	>15,000	>1,500	280	~100	N.A.

NOTE:

F.C. FECAL COLIFORMS

E.coli ESCHERICHIA COLI

P.a. PSEUDOMONAS AERUGINOSA

N.A. NOT AVAILABLE